Chapter 18

Lecture Outline*

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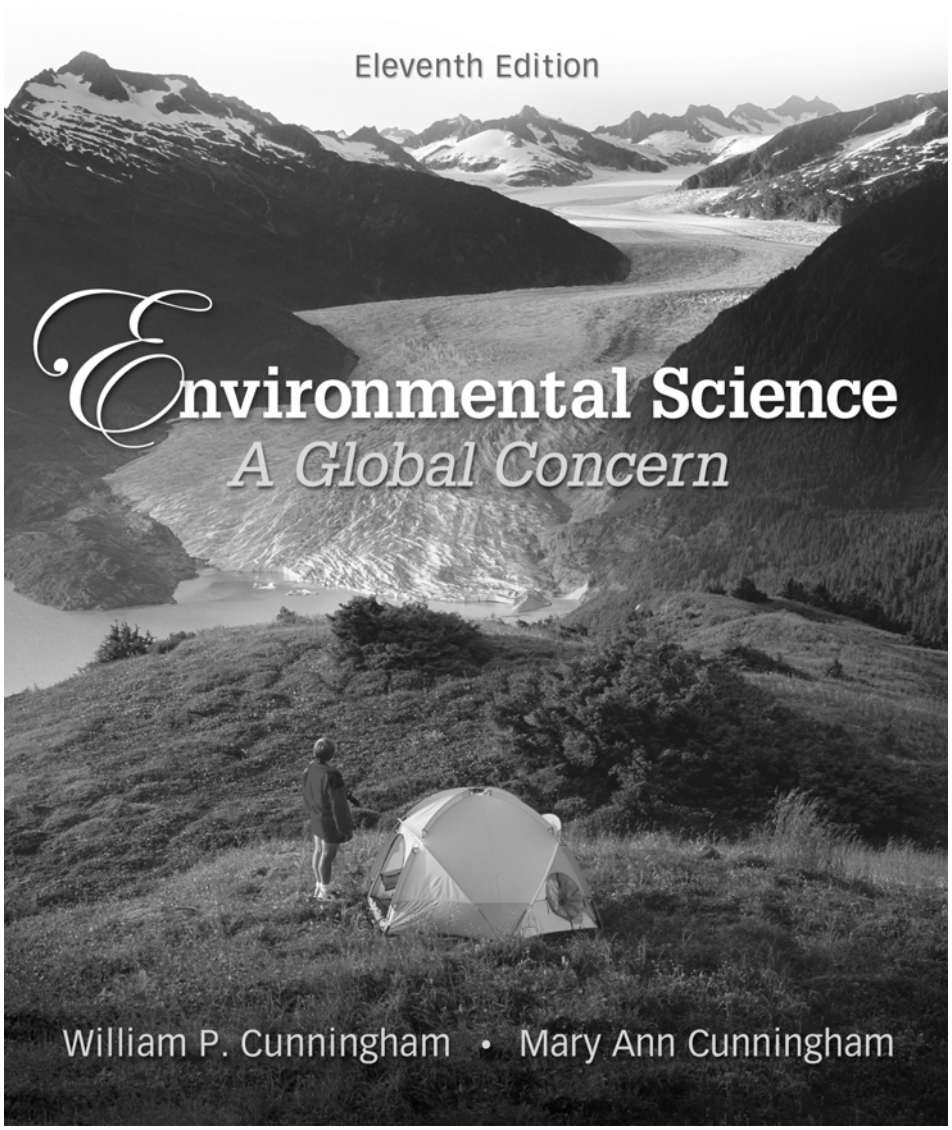

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Water Pollution

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Outline

- Types and Effects of Water Pollution
  - Point vs. Non-Point Sources
- Water Quality Today
  - Surface Water
  - Groundwater
  - Ocean Water
- Water Pollution Control
  - Source Reduction
  - Municipal Sewage Treatment
- Water Legislation
  - Clean Water Act (1972)

Water Pollution

- Any physical, biological, or chemical change in water quality that adversely affects living organisms or makes water unsuitable for desired uses can be considered pollution.
  - Point Sources - discharge pollution from specific locations
    - Factories, power plants, drain pipes
  - Non-Point Sources - scattered or diffuse, having no specific location of discharge
    - Agricultural fields, feedlots

Water Pollution

- Non point sources continued
  - Atmospheric Deposition - contaminants carried by air currents and precipitated into watersheds or directly onto surface waters as rain, snow or dry particles
  - Estimated 600,000 kg of the herbicide atrazine in the Great Lakes
    - Most thought to have been deposited from the atmosphere
  - Contaminants can also evaporate from lakes.

Types and Effects of Water Pollution

- Infectious Agents
  - Main source of waterborne pathogens is improperly treated human waste
    - Animal waste from feedlots and fields is also important source of pathogens.
      - At least 2.5 billion people in less developed countries lack adequate sanitation, and about half of these lack access to clean drinking water.

Infectious Agents

- In developed countries, sewage treatment plants and pollution-control devices have greatly reduced pathogens.
  - Coliform bacteria - intestinal bacteria; used to detect water contamination
  - Drinking water generally disinfected via chlorination

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Oxygen-Demanding Wastes

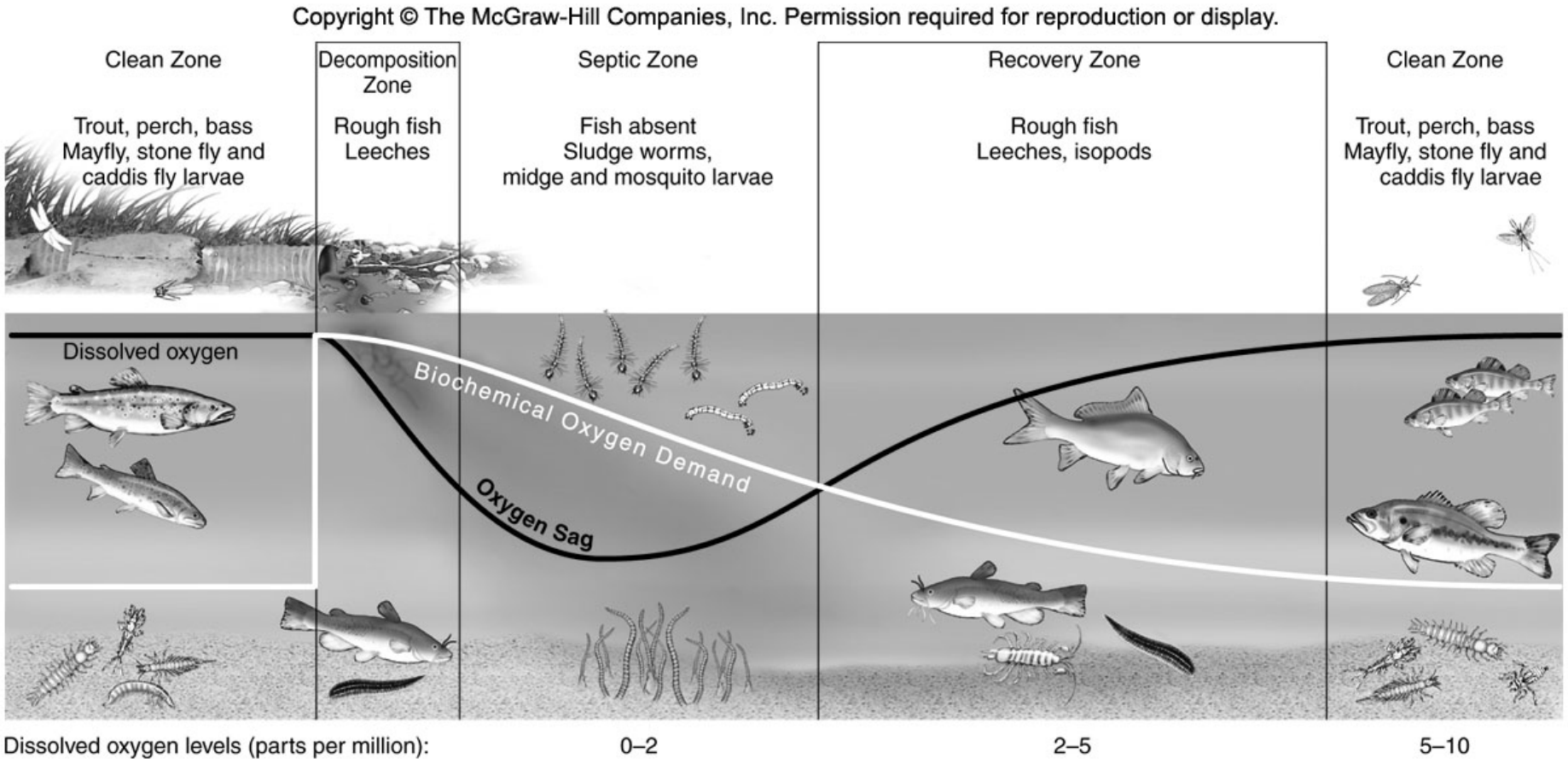
- Water with an oxygen content > 6 ppm will support desirable aquatic life.
  - Water with < 2 ppm oxygen will support mainly detritivores and decomposers.

- Oxygen is added to water by diffusion from wind and waves, and by photosynthesis from green plants, algae, and cyanobacteria.
  - Oxygen is removed from water by respiration and oxygen-consuming processes.

Oxygen-Demanding Wastes

- Biochemical Oxygen Demand - amount of dissolved oxygen consumed by aquatic microorganisms. Used as a test for organic waste contamination.
- Dissolved Oxygen Content - measure of dissolved oxygen in the water
- Effects of oxygen-demanding wastes on rivers depend on volume, flow, and temperature of river water.
  - Oxygen Sag - oxygen levels decline downstream from a pollution source as decomposers metabolize waste materials

Oxygen Sag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Clean Zone
Trout, perch, bass
Mayfly, stone fly and
caddis fly larvae
Decomposition Zone
Rough fish
Leeches
Septic Zone
Fish absent
Sludge worms,
midge and mosquito larvae
Recovery Zone
Rough fish
Leeches, isopods
Clean Zone
Trout, perch, bass
Mayfly, stone fly and
caddis fly larvae
Dissolved oxygen
Biochemical Oxygen Demand
Oxygen Sag
Dissolved oxygen levels (parts per million):
0–2
2–5
5–10

Plant Nutrients and Cultural Eutrophication

- Oligotrophic - bodies of water that have clear water and low biological productivity
- Eutrophic - bodies of water that are rich in organisms and organic material
  - Eutrophication - process of increasing nutrient levels and biological productivity
    - Cultural Eutrophication - increase in biological productivity and ecosystem succession caused by human activities
      - Algal blooms often result. Decomposing algae rob water of oxygen.

Toxic Tides

- Red tides - dinoflagellate blooms - have become increasingly common in slow-moving and shallow waters.
  - Dinoflagellates are single-celled organisms that swim with 2 whiplike flagella.
    - *Pfiesteria piscicida* is a poisonous dinoflagellate recently recognized.
  - Found in marine zones that are hypoxic due to eutrophication e.g. dead zone at mouth of Mississippi River

Inorganic Pollutants

- Metals
  - Many metals such as mercury, lead, cadmium, and nickel are highly toxic.
    - Highly persistent and tend to bioaccumulate in food chains
    - Most widespread toxic metal contaminant in North America is mercury (found in fish)
      - 600,000 American children have mercury levels high enough to cause mental deterioration and 1 woman in 6 has levels high enough to harm fetus.

Other Metal Contaminants in Water

- Mine drainage and leaching are serious sources of environmental contamination.
  - In a Tennessee study, 43% of streams and 50% of groundwater contaminated by metals and acid from mine drainage

Inorganic Pollutants

- Nonmetallic Salts
  - Many salts that are non-toxic at low concentrations can be mobilized by irrigation and concentrated by evaporation, reaching levels toxic to plants and animals.
    - Leaching of road salts has had detrimental effect on many ecosystems.
    - Arsenic in India and Bangladesh

Acids and Bases

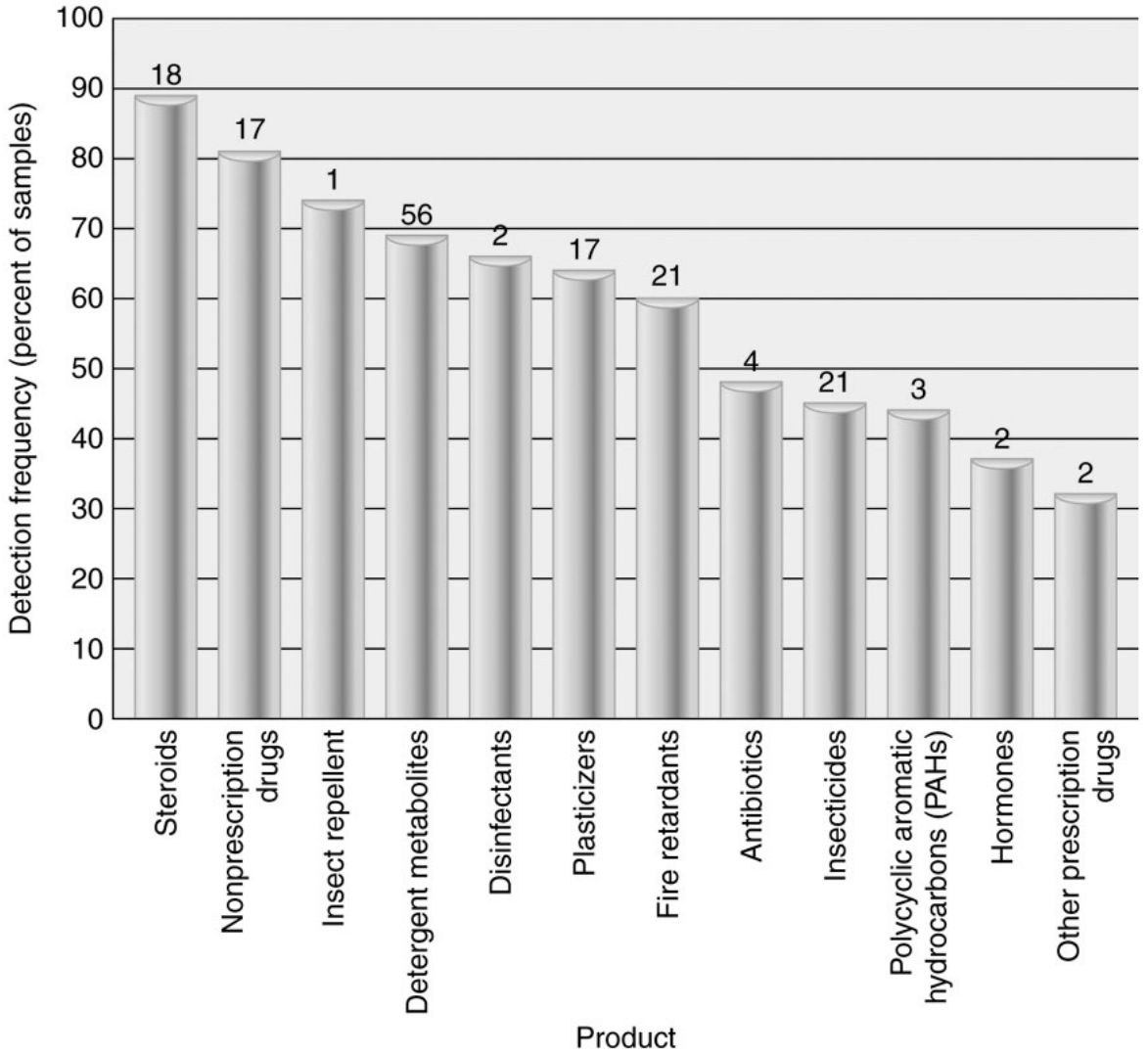
- Acids and Bases
  - Often released as by-products of industrial processes
  - Coal mining is an especially important source of acid water pollution.
    - Many streams acidified by acid mine drainage are lifeless
  - Combustion of fossil fuels releases sulfuric and nitric acids that are deposited in water.
    - Thousands of lakes are empty of fish and support only a few mosses and fungi due to low pH.

Organic Chemicals

- Thousands of natural and synthetic organic chemicals are used to make pesticides, plastics, pharmaceuticals, pigments, etc.

- Two most important sources of toxic organic chemicals in water are:
  - Improper disposal of industrial and household wastes
  - Runoff of pesticides from fields, roadsides, golf courses, lawns, etc.

Detection Frequency of Organic Contaminants



Sediment

- Human activities have accelerated erosion rates in many areas.
  - Human-induced erosion and runoff contribute about 25 billion metric tons of sediment and suspended solids to world surface waters each year.
    - Obstructs shipping channels, clogs hydroelectric turbines, smothers fish eggs, blocks out light needed for photosynthesis
    - Sediment can also be beneficial e.g. building coastal wetlands and nourishing floodplain fields

Thermal Pollution

- Raising or lowering water temperatures from normal levels can adversely affect water quality and aquatic life.
  - Oxygen solubility in water decreases as temperatures increase.
    - Species requiring high oxygen levels are adversely affected by warming water.
    - Humans cause warming by discharging heated water from power plants and other industries.

Thermal Pollution

- Industrial cooling processes often use heat-exchangers to extract excess heat, and then discharge heated water back into original source as a thermal plume.
  - Disrupts natural ecosystems
    - Die off of heat sensitive organisms
    - Other organisms are attracted to warmth, but die when flow of warm water is interrupted by plant shutdown.
  - Cooling ponds or towers needed

Water Quality Today

- Areas of Progress
  - Clean Water Act (1972) established a National Pollution Discharge System which requires a permit for any entity dumping wastes in surface waters and requires disclosure of what is being dumped.
    - Significant improvement in water quality, mostly due to sewage treatment
    - But goals have not been fully met; 21,000 water bodies do not meet designated uses

Areas of Progress

- In 1998, EPA switched regulatory approaches. Rather than issue standards on a site by site basis, the focus is now on watershed-level monitoring and protection.
  - States are required to identify waters not meeting water quality goals and develop total maximum daily loads for each pollutant and each listed water body.
    - Encouraging example: Lake Erie

Remaining Problems

- Some of the greatest impediments to achieving national goals in water quality are sediment, nutrients, and pathogens, especially from non-point discharges.
  - About three-quarters of water pollution in the U.S. comes from soil erosion, air pollution fallout, and agricultural and urban runoff.
    - Cattle in feedlots produce 144 million tons of manure and pet waste does not go through sewage treatment.

Other Countries Also Have Water Pollution

- Sewage treatment in wealthier countries of Europe generally equals or surpasses the U.S.
- In Russia, only about half of the tap water supply is safe to drink and in China 70% of surface waters are unfit for consumption.
- South America, Africa and Asia have poor water quality due to poverty, population growth and shift of polluting industries from countries where laws are strict to where they are lax.
- The Yamuna River and 2/3 of the other surface waters in India are so polluted that it is dangerous to even have contact with the water.

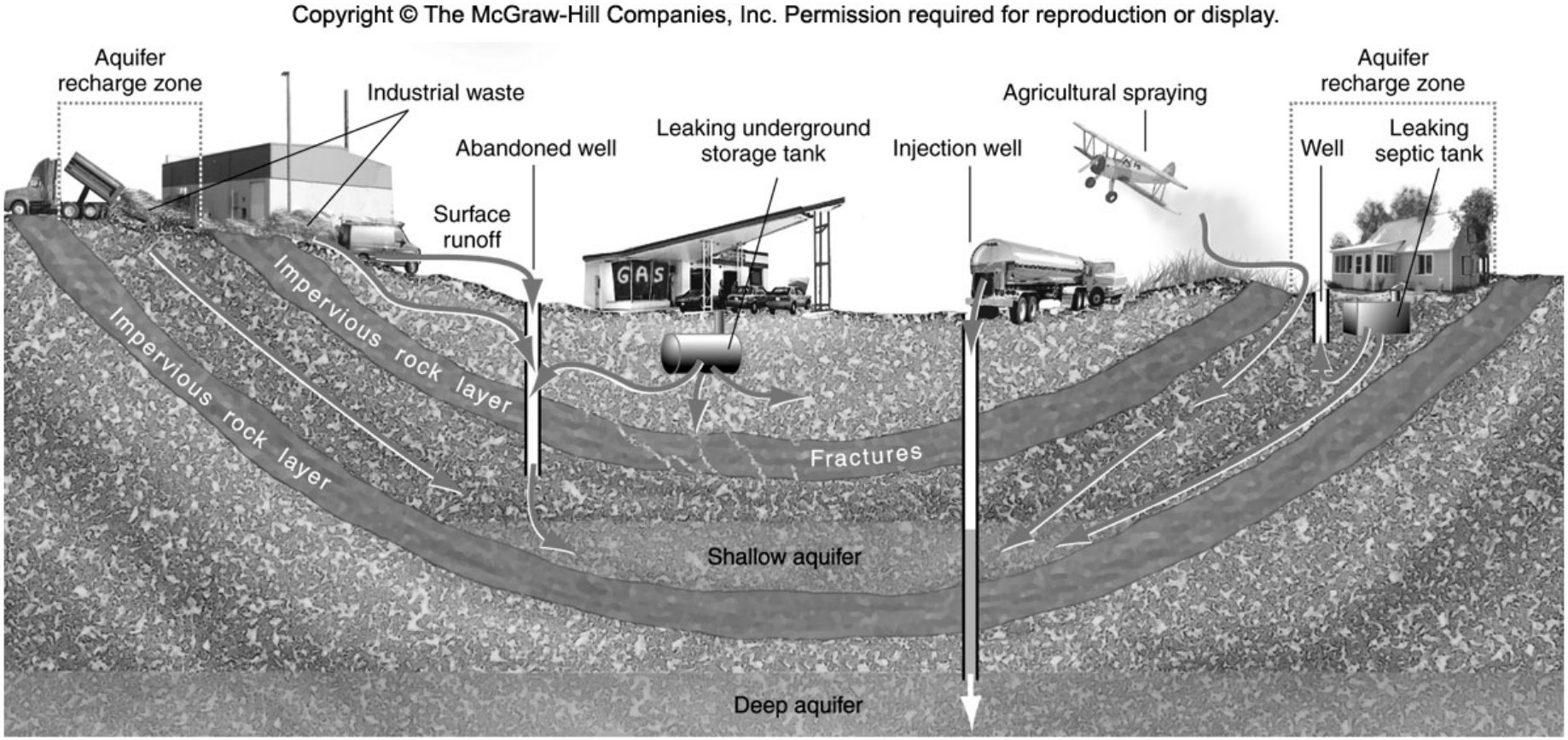
Groundwater Is Hard To Monitor And Clean

- About half the U.S. population, and 95% of rural residents, depend on underground aquifers for drinking water.
  - For decades, groundwater was assumed impervious to pollution and was considered the gold standard for water quality, but that is no longer true.
  - Methyl tertiary butyl ether (MTBE). a suspected carcinogen found in gasoline, now contaminates groundwater.

Groundwater and Drinking Water

- EPA estimates 4.5 trillion liters (1.2 trillion gal) of contaminated water seep into the groundwater in the U.S. every day.
  - Comes from septic tanks, cesspools, landfills, waste disposal sites, etc.
    - 1 gal of gasoline can make 1 million gal of water undrinkable.
  - In agricultural areas, fertilizers and pesticides commonly contaminate aquifers and wells.
  - Contaminants remain for thousands of years

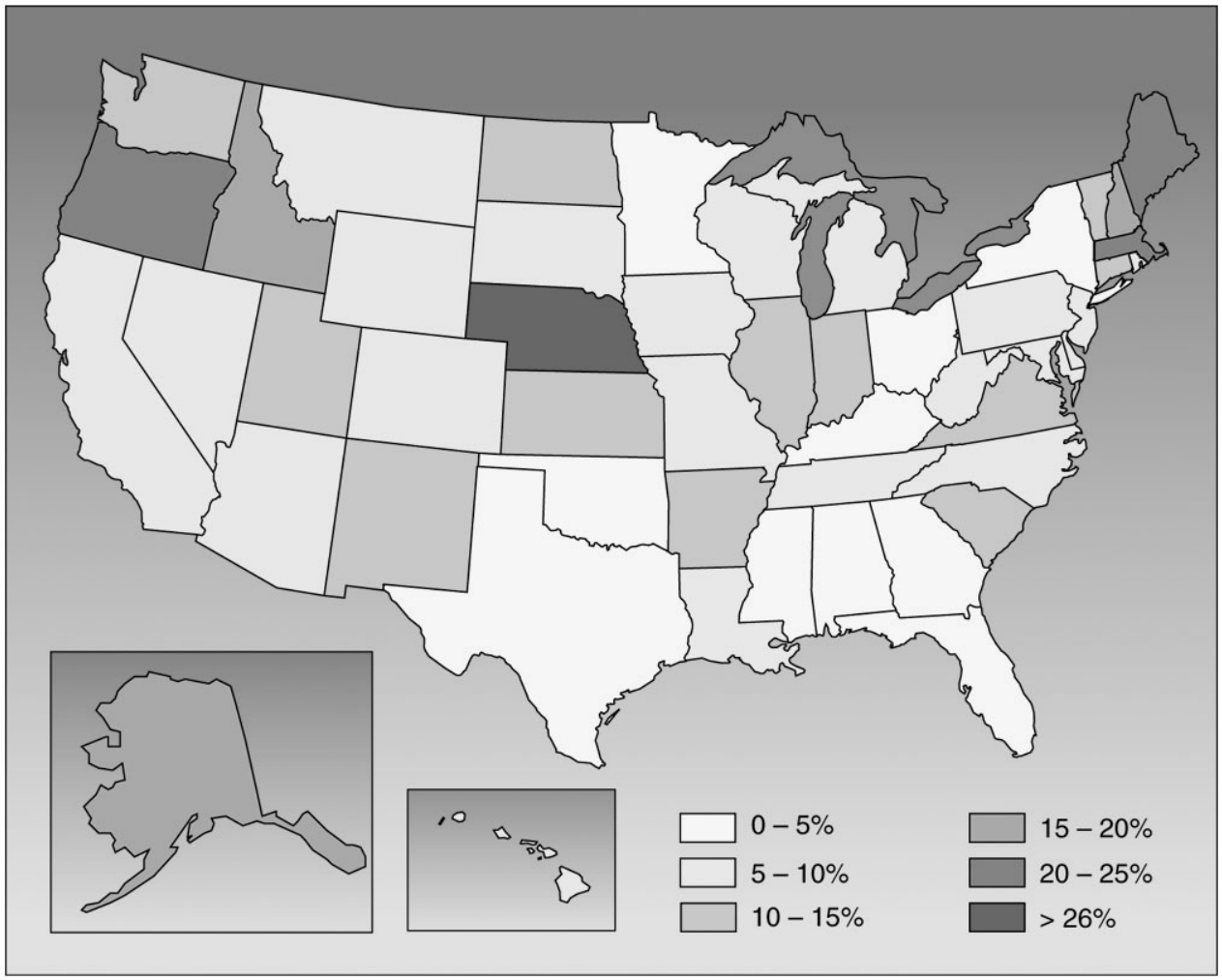
Groundwater Pollution



Groundwater and Drinking Water

- In addition to groundwater, contaminated surface waters can make drinking water unsafe.
  - 2008 EPA data show that 30,000 people in the U.S. get water from community systems that don't meet all health-based drinking water standards
- An estimated 1.5 million Americans fall ill from fecal contamination annually
  - *Cryptosporidium* outbreaks
    - Milwaukee - 400,000 sick, 100 dead

Drinking Water Systems with EPA Violations



There Are Few Controls On Ocean Pollution

- Coastal zone often overwhelmed by contamination from heavy metals, toxic chemicals, oil, pathogens, sediment. These zones would otherwise be among most productive.
  - Discarded plastics are non-biodegradable, last for years, and are carried by currents around the world.
    - Often ensnare bird and mammals, choking them

Ocean Pollution

Courtesy of Joe Lucas/Marine Entanglement Research Program/National Marine Fisheries Service NOAA

Oil Pollution

- Few coastlines in the world remain uncontaminated by oil pollution.
  - 3 to 6 million tons of oil are released into ocean each year, about half of which is due to marine transport.
  - Major oil spills from transport, military conflict, oil drilling in risky locations such as the North Sea
  - There are plans to drill in seismically active California and Alaskan coasts.

Source Reduction Can Reduce Water Pollution

- Cheapest and most effective way to reduce pollution is avoid producing it or releasing it into the environment.
  - Studies show as much as 90% less road salt can be used without significantly affecting safety.
  - Carefully dispose of oil
  - Recover metals from industrial waste and sell them

Land Management Controls Nonpoint Sources

- Some main causes of nonpoint pollution:
  - Agriculture
  - Urban runoff
  - Construction sites
  - Land disposal
- Generally, soil conservation methods also help protect water quality.
- In urban areas, reducing materials carried away by storm runoff is helpful.

Signs Can Remind People Where Wastes Go

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Human Waste Disposal

- More than 500 pathogenic bacteria, viruses, and parasites can travel from human or animal excrement through water.
- Natural Processes
  - In many areas, outdoor urination and defecation is the norm.
    - When population densities are low, natural processes can quickly eliminate waste, but in cities this is unworkable.
      - A significant proportion of dust in Mexico City is actually dried feces.

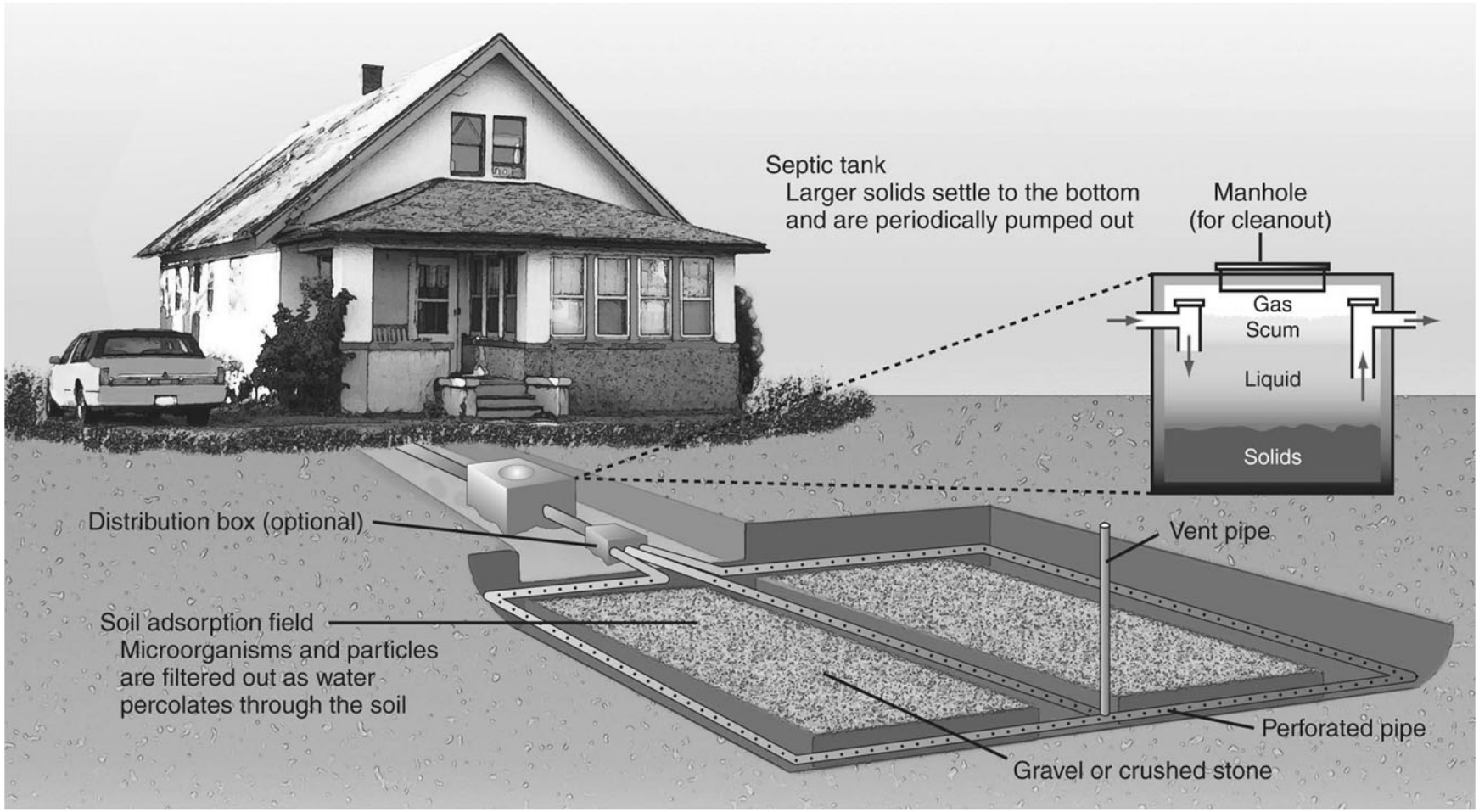
Human Waste Disposal

- In many countries, especially in Asia, “night soil” (human and animal waste) is spread on fields as fertilizer, but it can cause disease.

- Until about 70 years ago, most rural areas in the U.S. depended on outhouses, which contaminated drinking water supplies.

- Development of septic fields which clean water by aeration and remove excess nutrients through bacterial action. Solids are pumped out and taken to a treatment plant.

Septic Tank



Municipal Sewage Treatment

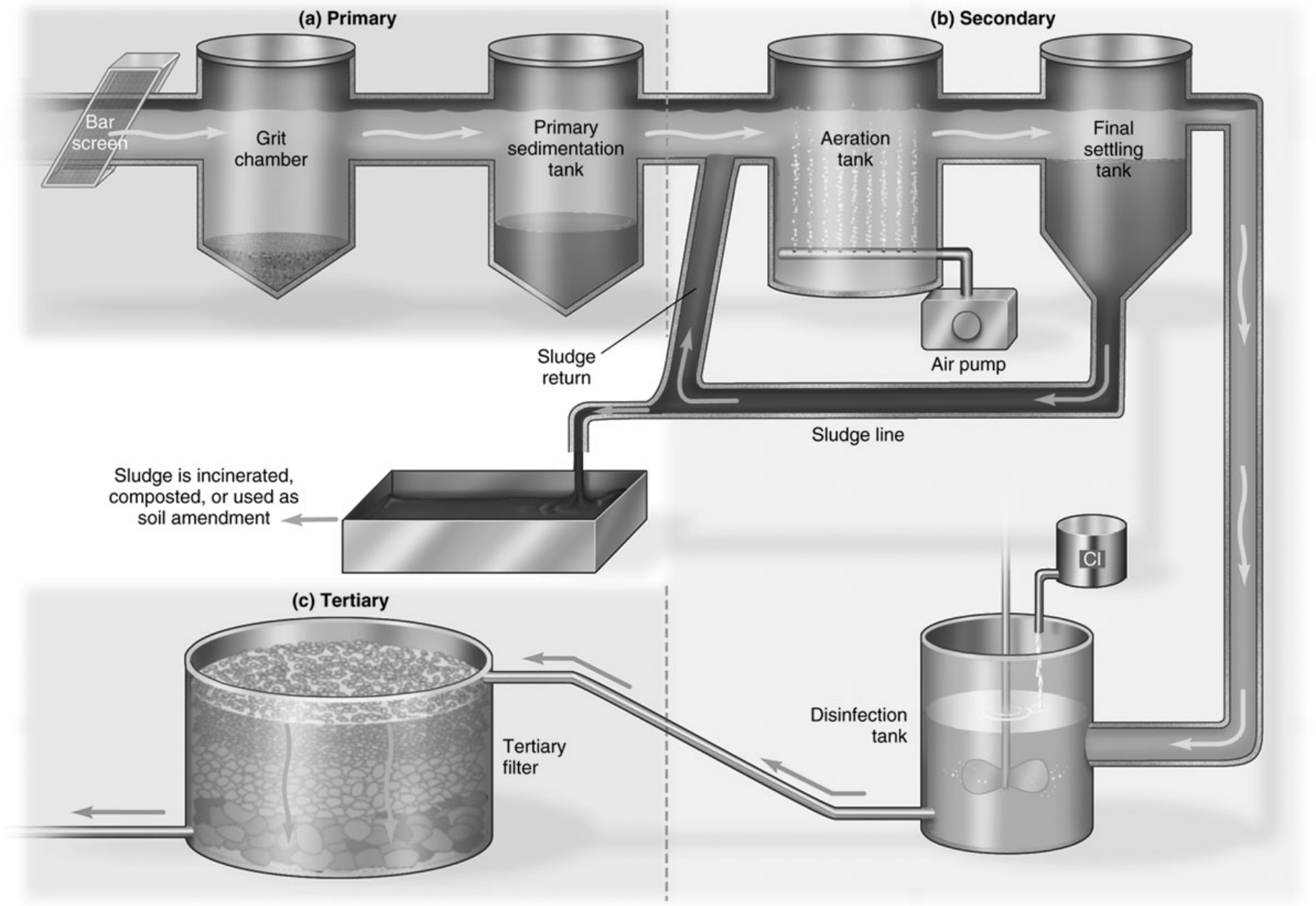
- Primary Treatment - physical separation of large solids from the waste stream

- Secondary Treatment - biological degradation of dissolved organic compounds
  - Effluent from primary treatment transferred into trickling bed, or aeration tank
    - Effluent from secondary treatment is usually disinfected (chlorinated) before release into nearby waterway.

Municipal Sewage Treatment

- Tertiary Treatment - removal of plant nutrients (nitrates and phosphates) from secondary effluent
  - Chemicals which bind or natural wetlands

- In many U.S. cities, sanitary sewers are connected to storm sewers.
  - Heavy storms can overload the system, causing by-pass dumping of raw sewage and toxic runoff directly into watercourses.



Low-Cost Waste Treatment

- Effluent Sewerage
  - Hybrid between traditional septic tank and full sewer system
    - Pump liquid tank contents to central treatment plant rather than use drainfield

- Wetlands
  - Effluent flows through wetlands where it is filtered and cleaned by aquatic plants and microscopic organisms.

Water Remediation

- Containment methods confine liquid wastes in place, or cap surface with impermeable layer to divert water away from a site that is causing pollution.
- Extraction techniques are used to pump out polluted water for treatment.
  - Oxidation, reduction, neutralization, or precipitation of contaminants
- Living organisms can also be used to break down pollution (called bioremediation).

Ecological Engineering

- Ocean Arks International designs vessels that combine living organisms with containment. In a machine, water flows through a series of containers, each with a distinctive biological community. Waste from one vessel becomes the food for the next vessel.

- Final effluent is technically drinkable, but more often used for irrigation or flushing toilets.

Water Legislation

- U.S. Clean Water Act (1972)
  - Goal was to return all U.S. surface waters to "fishable and swimmable" conditions
    - For point sources, discharge permits and best practicable control technology (BPT) are required.
      - Set goals of best available, economically achievable technology (BAT) for zero discharge of 126 priority toxic pollutants

Clean Water Act (1972)

- Areas of Contention
  - Draining or filling of wetlands is regulated
    - Farmers and developers consider this the taking of private lands
  - Unfunded Mandates
    - State or local governments must spend monies to comply with regulations but are not repaid by Congress.
  - Agricultural runoff is largest source of surface water degradation, but regulation remains a problem.

Other Important Water Legislation

- Safe Drinking Water Act regulates water quality in municipal and commercial systems

- CERCLA (1980) created Superfund program to clean up toxic waste sites
  - Amended in 1884 by SARA, which provides immediate response in emergency situations and permanent remedies for abandoned sites

Clean Water Legislation

Table 18.2 Some Important U.S. and International Water Quality Legislation
1. *Federal Water Pollution Control Act* (1972). Established uniform nationwide controls for each category of major polluting industries.
2. *Marine Protection Research and Sanctuaries Act* (1972). Regulates ocean dumping and established sanctuaries for protection of endangered marine species.
3. *Ports and Waterways Safety Act* (1972). Regulates oil transport and the operation of oil handling facilities.
4. *Safe Drinking Water Act* (1974). Requires minimum safety standards for every community water supply. Among the contaminants regulated are bacteria, nitrates, arsenic, barium, cadmium, chromium, fluoride, lead, mercury, silver, pesticides; radioactivity and turbidity also are regulated. This act also contains provisions to protect groundwater aquifers.
5. *Resource Conservation and Recovery Act* (RCRA) (1976). Regulates the storage, shipping, processing, and disposal of hazardous wastes and sets limits on the sewering of toxic chemicals.
6. *Toxic Substances Control Act* (TOSCA) (1976). Categorizes toxic and hazardous substances, establishes a research program, and regulates the use and disposal of poisonous chemicals.
7. *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) (1980) and *Superfund Amendments and Reauthorization Act* (SARA) (1984). Provide for sealing, excavation, or remediation of toxic and hazardous waste dumps.
8. *Clean Water Act* (1985) (amending the 1972 Water Pollution Control Act). Sets as a national goal the attainment of "fishable and swimmable" quality for all surface waters in the United States.
9. *London Dumping Convention* (1990). Calls for an end to all ocean dumping of industrial wastes, tank washing effluents, and plastic trash. The United States is a signatory to this international convention.